INTERNATIONAL ATOMIC WEIGHTS.

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Near the close of the year 1897, the German Chemical Society appointed a committee to select values of the atomic weights for common use in Germany. The confusion arising from the use of different values, and especially of different standards of reference, had become unbearable. After nearly a year's deliberation, they announced their conclusion that it is expedient to call oxygen exactly 16, and to refer other elements to this standard. They published a carefully considered and conservative table of values,* which immediately gained wide acceptance, partly because of its intrinsic merits, and partly because it was vouched for by such eminent men as Landolt, Ostwald, and Seubert. At the close of the remarks accompanying this table, the three members of the committee expressed their hope that the matter might be clinched by international agreement. The hope was strengthened by the fact that the two other modern tables, those of Clarke and of Richards, differed but slightly from the table presented in Germany. Time has strengthened this hope still further, for the two subsequent yearly editions of the three tables have steadily tended toward the elimination of earlier differences, until now they are even more alike than they were at first. †

On March 30, 1899, having heen encouraged by the favorable reception of their work, the German committee issued to all important associations interested in chemistry throughout the world a general invitation to appoint delegates to an International Committee. ‡ The number of delegates was not determined, and the outcome was the appointment of fifty-seven men from among the most eminent chemists of eleven nations. As representatives on this International Committee the American Chem-

* Ber. d. deutsch. chem. Gesell., **31**, 3761 (1898).

† See Journ. Am. Chem. Soc., **22**, 78 (1900); also, These Proceedings, **35**, 621 (1900), and Ber. d. deutsch. chem. Gesell., **33**, 1 (1900).

‡ Ber. d. deutsch. chem. Gesell., **31**, 2949 (1898); **33**, 1847 (1900).

ical Society appointed Professors F. W. Clarke, J. W. Mallet, E. W. Morley, T. W. Richards, and E. F. Smith. Shortly afterward the American Academy of Arts and Sciences added Professors Wolcott Gibbs and Ira Remsen to the list of American delegates. Besides these seven men, the present International Committee contains fifteen from Germany, eleven from Austria, eight from England, five from Belgium, three each from Switzerland and Italy, two from Japan, and one each from Holland, Russia, and Sweden. It is much to be regretted that Denmark, France, and Norway have as yet made no appointments.

Having thus received very general support, the German committee, in October, 1899, decided upon another step. They forwarded to each member of the International Committee a circular letter containing three questions, which were speedily answered by nearly all of the delegates. A literal translation of these questions follows: —

"1. Shall $O = 16$ be fixed as the future standard for the calculation of atomic weights?

"2. Shall the atomic weights be given with so many decimals that the last figure is certain within half a unit, or what other procedure shall be adopted?

"3. Is it desirable that a smaller committee should be formed, which should undertake the continual revision of the yearly atomic weight table and its publication? In case of agreement upon this point, it is proposed that each association name a single delegate to this smaller committee."

The forty-nine answers to these questions are highly interesting.* As regards the first question, only seven chemists (one American and six Germans) were decidedly in favor of retaining hydrogen as the standard, while forty were decidedly of the opposite opinion. Two were willing to accept either or both standards of reference. In spite of the fact that men as eminent as Professors Mallet, Volhard, Winkler, and Wislicenus are in the minority, the majority is so overwhelming that we must look upon this point as settled for a long time. Even if the probable delegates from the unrepresented countries should all vote in the negative, the majority must remain in favor of $O = 16$. Thus the new term, "international atomic weight," is perfectly clear and unequivocal in its meaning as to the standard of reference, and an important step has been made.

It may not be irrelevant here to enumerate the advantages and disad-

* Ber. d. deutsch. chem. Gesell., **33**, Heft 12, p. 1850 (1900). The answers are published in full.

vantages of this international standard. In the first place, it is evident that the question is a practical one, not a theoretical one. If Prout's ancient hypothesis seemed at all probable, there would indeed be a strong reason for assuming hydrogen as unity; but Prout's hypothesis cannot now claim serious consideration, at any rate in its original form. No other theoretical reason for calling hydrogen exactly 1.000 is known to me. What, then, are the relative *practical* advantages to be gained by taking hydrogen or oxygen as the standard? In the first place, the precise quantitative analysis of compounds containing hydrogen is a very difficult matter, and water is the only one which has been adequately studied. Hence nearly all atomic weights must be referred to hydrogen through the medium of oxygen; and if the ratio H : O is found to be even a little in error, all other values must be recalculated. Morley's work on this ratio is indeed magnificent, and it is not likely that his accuracy can be surpassed for a long time; nevertheless the principle still remains. Oxygen, on the other hand, has been directly compared with many metals, as well as with potassic chloride and similar salts obtainable from the chlorates and their analogues. Hence from the point of view of directness of comparison, oxygen is to be preferred. Silver might be even better, as Erdmann and Volhard point out in their replies to the circular letter; but the question does not concern the starting of an entirely new system, but rather the choice between two old ones.

Another point to be considered is the effect of the decision upon the data contained in the past literature of chemistry. Any change which might confuse the understanding of the work of the past would be indeed a grievous one; and a change to O = 15.879 could not but have this effect. Little or nothing has been written with the assumption of this standard, while a great bulk has been written with the assumption O = 16. The confusion caused by the inaccurate value O = 15.96 is quite bad enough, without the introduction of a new stumbling-block. Moreover, in the gas constant and a multitude of other physico-chemical constants the value O = 16 enters, and a change in this standard would complicate the use of a great mass of valuable literature of this kind.

Another, although somewhat trivial, reason why oxygen should be taken as 16 is because in that case a somewhat larger proportion of the atomic weights approximate whole numbers than would be the case otherwise.

The chief objection to the proposed standard is a pedagogical one. It is claimed that confusion is caused in the mind of the elementary student

by the use of the number 1.0075.* The German committee points out in its last report that this difficulty may be avoided by giving the elementary student only the round numbers (which suffice amply for his purpose), accompanied by the statement that these are rough approximations. There is obviously another way of avoiding the confusion, and that is by doing away with hydrogen as a standard of specific gravity. The difficulty of preparing this gas in a pure state and its great lightness are arguments against it, in any case. Moreover, in my experience the simplicity of the relationship between the specific gravity referred to hydrogen and the molecular weight is quite as likely to be a stumbling-block as an assistance. Many a beginner learns by heart the statement that the specific gravity is twice the molecular weight; for he does not pause to think about it and see that he has inverted the ratio. If, on the other hand, the specific gravity of oxygen is taken as the standard, the adverse arguments disappear, and even a dull student can hardly forget the reason why the specific gravity of the gas X referred to oxygen must be multiplied by 32 to give the molecular weight. For several years I have used this method with large classes, and find that it gives no trouble. The only data needing recalculation are the specific gravities of the gases, and that is a simple matter. It seems to me, by the way, that the use of 2 instead of R in physico-chemical formulae has the same pedagogic fault of obscuring the source and nature of the symbol.

The answers to the second international question, which seeks to determine the number of decimal places to be given, support the German committee in its position with a majority almost as overwhelming as in the case of the first question. The minority of eight consists of three Americans, three Germans, and two Japanese, all the others desiring to omit all figures which are not certain to within half a unit. The committee, in summing up the opinions upon this subject, states that its desire is to propose a table for common use, and that the minority, which desires the retention of one uncertain decimal place, has rather had in mind the requirements of work of the greatest precision. Undoubtedly the curtailed table will answer for most purposes, but it seems to me that the nature of the decimal notation causes an unfortunate incompleteness in it. Although, in the face of so great a majority, this matter, like the other, must be considered as settled, I am tempted to call attention to this incompleteness in relation to numerical data of all kinds.

* Much has been written upon both sides of this question. Besides the articles already referred to, many references may be found in two papers by Küster and Brauner (Zeit. anorg. Chem. **14**, 251 and 257 respectively (1897)).

Let us consider a concrete example, — the case of nitrogen. Few would be willing to contend that the last figure in the number 14.04 is certain. For the sake of argument, let us assume that the value of this atomic weight may really be as low as 14.034 or as high as 14.046. According, then, to the rule which has just been adopted by the International Committee, this figure 4 should be omitted, and nitrogen should be called 14.0. Such an omission causes an error far greater than the uncertainty which leads to the dropping of the figure. The uncertainty named above is only 0.04 per cent, but the minimum error in the value 14.0 is 0.24 per cent, if the lower value given above is supposed to be the lowest possible. Clearly one must either record uncertain figures, or else omit figures which have a real significance. The dropping of a decimal place at once reduces tenfold the ability of a number to express slight changes of value; but numerical results may have any degree of accuracy, and cannot be classed strictly into classes separated by gaps so wide. For this reason it is a well-known practice in scientific calculation to retain during the calculation one uncertain figure, while a final result is sometimes relieved of this uncertain figure. According to this rule, the table of atomic weights should always give an uncertain figure in each value; for atomic weights are simply data for further calculation. If this is done, the user has all the truth, and may reject as much of it as his occasion permits. Such a table of atomic weights seems to me to be the best, because it is capable of fulfilling all uses.

Quite another point of view should be adopted in making a table solely for common use. Here we are concerned not with the number of certainly ascertained figures which may have been determined by Stas, but rather with those figures which will have an influence upon the work in hand. Usually the error in such a value is important not on account of its absolute magnitude, but rather on account of its relation to the value itself. In short, the percentage error is that which ought to be considered in constructing a table of atomic weights for common use. A majority of chemists would probably decide that a table in which the values were within 0.1 per cent of their true values would serve all ordinary purposes. Most common methods are not able to attain as great a degree of accuracy even as this, but the admission of a wider range of inaccuracy in a table of atomic weights might by summation cause an appreciable error. Silver might be called 108.0, chlorine 35.5, bromine 80.0, iodine 126.9, potassium 39.2, sulphur 32.1, and lead 207.0, without seriously affecting the results of most quantitative work, and indeed every one frequently uses such approximate values. Even in this approximate

table hydrogen should be 1.008, and not 1.01, if the percentage rule is to be followed.

The last question asked by the German committee, suggesting the appointment of a small standing committee, was answered affirmatively by every one. The original plan of having a representative from each society would evidently result in the formation of an unwieldy body; hence the German committee has wisely concluded that a small number, perhaps three, one each from Germany, England, and the United States, should be elected from among those who have had especial experience in the matter of atomic weights.

The matter is by no means finished. The German committee asks any one who has anything new to say upon the questions under consideration to send a brief statement of his views to Professor Landolt before November 15; and some new ideas may have been advanced in the discussion in Paris at the end of July. The balloting for the election of the smaller International Committee is already in progress.

The German Chemical Society, as well as the members of its committee, is greatly to be congratulated on the success of the undertaking, not only because of the immediate gain to chemistry, but also because of the manifest advantages of the growth of scientific coöperation between men of all nations.

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